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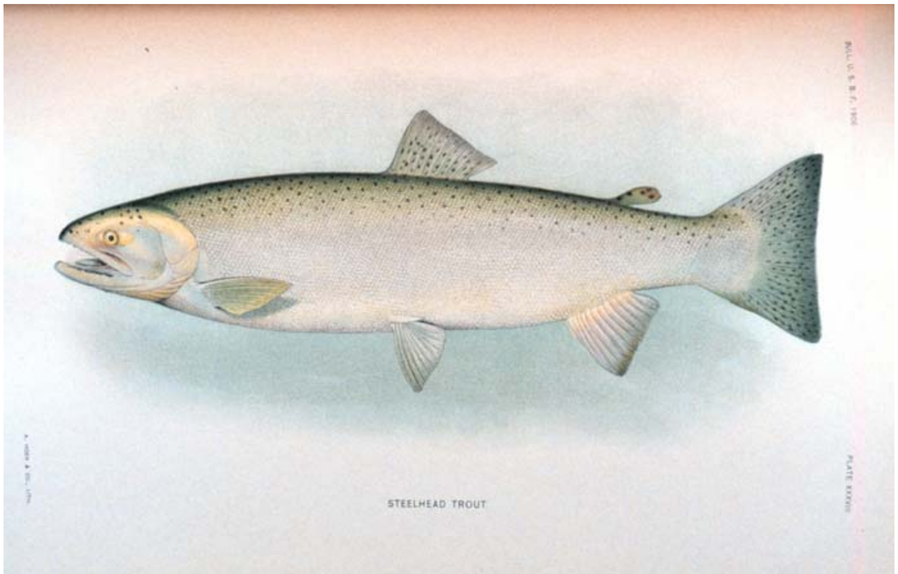

Oncorhynchus mykiss:

Assessment of Washington State's Anadromous Populations and Programs

Edited by
James B. Scott, Jr.
William T. Gill

Washington Department of Fish and Wildlife
Olympia, Washington

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Preface

This report was written by Washington Department of Fish and Wildlife (WDFW) staff with expertise in the specific topic discussed in a chapter. Primary contributors to each chapter are listed below.

Chapter 1. Introduction
James B. Scott, Jr.
William T. Gill

Chapter 2. Biology
Anne Marshall
Bob Leland
William T. Gill
James B. Scott, Jr.

Chapter 3. Artificial Production
Craig Busack
Pat Hulett
Todd Pearsons
Jack Tipping
James B. Scott, Jr.

Chapter 4. Management
James B. Scott, Jr.
Bob Leland
William T. Gill

Chapter 5. Population Structure
Ann Blakley
William T. Gill
James B. Scott, Jr.

Chapter 6. Diversity and Spatial Structure
Brian McTeague
Martin Hudson
Arleta Agun
William T. Gill
James B. Scott, Jr.

Chapter 7. Abundance and Productivity
Ann Blakely
Brad Thompson
Kristen Ryding
Kurt Reidinger
William T. Gill
James B. Scott, Jr.

The development, drafting, and review of this report has proceeded through a number of steps, many of which relied on entities outside of WDFW. The Hatchery Scientific Review Group, Steelhead and Cutthroat Policy Advisory Group, the Steelhead Summit Alliance, and some staff of western Washington tribes assisted in the identification of key questions and the development of a report outline. Previous drafts of this report have been reviewed by WDFW staff, the Steelhead and Cutthroat Policy Advisory Group (two occasions), and some staff of western Washington tribes. However, tribal staff assistance in the preparation and review of this report does not necessarily imply tribal agreement with report content.

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Executive Summary

From cold mountain streams to the Pacific Ocean, the waters that shape the landscape of the Pacific Northwest also define the lifecycle of native steelhead (*Oncorhynchus mykiss*). Fast and sleek, steelhead cover thousands of miles from the time they leave their natal streams for the open ocean, then return again – often more than once – to spawn. Known for their explosive power and their preference for fast-flowing rivers, these fish have long held a special place in the lore of Northwest anglers. Traditional Native American culture in the Pacific Northwest is also inextricably tied to steelhead and other anadromous salmonids. For many Northwest Indian peoples, these fish have always provided an essential source of food, a focal point of religious life and a central commodity for trade and commerce. A Northwest icon, steelhead were designated by the legislature as the Washington State fish in 1969.

Steelhead have also been the focus of significant controversy. Construction and operation of dams, habitat degradation, hatchery programs, and fishing have all sparked long and continuing debates, blue-ribbon panel reviews, and research papers. Two reviews of particular note -- "Upstream: Salmon and Society in the Pacific Northwest", by the National Research Council, and the Royal report, commissioned by the Washington Department of Game in 1973, have had a substantial impact on fishery management in the Pacific Northwest.

Why, in the face of the already extensive literature, have we invested substantial time and energy in the development of yet another report? This report is not simply an assessment of Washington's steelhead populations or a critique of current management practices. Rather, it is designed to lay the foundation for the development of improved management plans, scheduled to begin this year, that assure the productivity of Washington's steelhead for future generations. To achieve this goal, we established four primary objectives for this report:

1) **Promote Progress in the Continued Evolution of Fisheries Management.** The underlying paradigm for fishery management is rapidly shifting from an approach that focused simply on the abundance of a single species to one that considers multi-attribute population assessments and community ecology. Abundance,

productivity, spatial structure, and diversity all contribute to the maintenance of viable salmonid populations (VSP) (McElhany et al. 2000).

2) **Reduce Information Lag**. A significant lag often exists between the completion of research or a monitoring project and its application in management. We seek to reduce information lag by providing access to cutting-edge analyses, including new methods for evaluating hatchery programs, assessing the historical distribution of steelhead, and estimating the risk of extinction.

3) **Collate Existing Data and Provide Statewide Perspective**. What is the status of Washington's steelhead populations and how do they vary throughout the state? Collation of existing information is a key step in the development of a management plan. Research in other parts of the state or the region can sometimes help answer a local question that has been difficult to resolve.

4) **Identify Critical Research, Monitoring, and Evaluation Needs**. The significant conservation concerns facing some steelhead populations and the rapid evolution in fishery management may require changes in monitoring and analysis. Preparation of this report provides an opportunity to evaluate our capabilities and identify key research, monitoring, and evaluation needs.

Our analyses, findings, and recommendations in these areas can be found in the seven chapters of this report and the extensive pages of supporting documentation. In this Executive Summary, we have attempted to highlight key points in the report and provide references to additional analyses. Topics in the Executive Summary are grouped into five categories: 1) Population Structure, Diversity, and Spatial Structure; 2) Habitat, Abundance, and Productivity; 3) Artificial Production; 4) Management; and 5) Additional Challenges and Opportunities. Within each of those categories, we provide the primary Findings and Recommendations of this report.

The development, drafting, and review of this report has proceeded through a number of steps, many of which relied on entities outside of WDFW. The Hatchery Scientific Review Group, Steelhead and Cutthroat Policy Advisory Group, the Steelhead Summit Alliance, and some staff of western Washington tribes assisted in the identification of key questions and the development of a report outline. Previous drafts of this report have been reviewed by WDFW staff, the Steelhead and Cutthroat Policy Advisory Group, and some staff of western Washington tribes. However, tribal staff assistance in the preparation and review of this report does not necessarily imply tribal agreement with report content.

Population Structure, Diversity, and Spatial Structure

The distribution of steelhead can be viewed from a variety of perspectives, ranging from the relatively fine scale of habitat patch utilization in a single stream to the distribution of populations throughout the range of the species. Characteristics of the environment at the lower levels of the hierarchy drive the adaptations of populations and provide the basic unit for the diversity of the species. The hierarchical organization of a salmonid species, Riddell (1993) concluded, implies that maintaining biological diversity necessarily requires conserving populations and the habitats on which they depend.

Findings and Recommendations:

- **Short-term abundance and long-term persistence of the steelhead resource requires viable, locally-adapted, diverse populations, but a substantial loss of population structure has occurred in some, but not all regions.** The percentage of historical populations remaining in 7 Washington regions ranges from 45%-100%. The two regions with 100% of the historical populations remaining - Olympia Peninsula and Southwest Washington - are both located on the Washington coast. The Upper Columbia River region has the smallest percentage of the historical populations remaining (45%). (Chapter 5, Finding 1)

- *O. mykiss* **displays a wide range of life history diversity that enables the species to persist in highly variable environments.** The diversity of life history characteristics expressed by *O. mykiss* include the presence of resident (rainbow or redband trout) and anadromous (steelhead) forms , varying periods of freshwater and ocean residency, summer and winter adult return timing to freshwater, and plasticity of life history between generations. The emphasis on life history diversity as a strategy for persistence contrasts with some other species of anadromous *Oncorhynchus*, such as pink salmon (*Oncorhynchus gorbuscha*), which exhibit relatively small variation in life history characteristics. (Chapter 2, Finding 1).

> *"The steelhead are a paradox and only their return is viewed with absolute certainty. They are composed of exceptions—every "fact" about their upstream migration will almost contain an opposite number somewhere else."*
>
> *Trey Combs, The Steelhead Trout*

- **A substantial loss of spatial structure and diversity of steelhead populations has occurred in some regions.** An estimated 9%-27% of historical winter steelhead habitat and 17%-30% of historical summer steelhead habitat in Washington is no longer accessible or utilized by steelhead. The largest reduction in utilization was in the Upper Columbia region, where an estimated 43%-52% of the historical habitat was no longer used by steelhead. The loss in spatial connectivity was categorized as "High" for 52% of the populations assessed statewide. For the 15 of 134 populations for which a diversity assessment could be completed, 73% had a "High" loss of diversity. (Chapter 6, Finding 1)

> *Recommendation.* Pursue opportunities to preserve and restore population structure, spatial structure, and within-population diversity through careful review of harvest, hatchery, and habitat management and implementation of improved strategies. (Chapter 2, Recommendation 1; Chapter 5, Recommendation 1; Chapter 6, Recommendation 1)

- **Increased emphasis on monitoring the diversity of *O. mykiss* populations is needed.** The assessment programs of WDFW, like many other resource management agencies, have traditionally focused on evaluating and monitoring abundance. However, fishery management is rapidly evolving with increased recognition of the importance of diversity in maintaining viable, productive populations. Unlike spawner abundance data, no consistent metrics, protocols, or structure for reporting and analysis of diversity currently exists. The lack of a monitoring program is of special concern for steelhead because of the wide range of life histories expressed by this species, the potential effects of artificial production, fishery harvest, and habitat modifications on diversity, and the reductions in diversity noted in some populations. (Chapter 6, Finding 2).

> *Recommendation.* Design and initiate a program to monitor the genotypic and phenotypic characteristics of steelhead populations and a management structure for analysis and reporting. Expanding the scope of the Salmonid Stock Inventory[1] (SaSI) to include data pertaining to diversity and spatial structure as well as spawner abundance data would promote concurrent reporting of all four of the viable salmonid population (VSP) characteristics. (Chapter 6, Recommendation 2).

[1] SaSI provides a central repository for information on the abundance, status, and stock origin of naturally spawning salmonids in Washington.

Habitat, Abundance, and Productivity

Abundance and productivity are two of the four VSP characteristics that determine the health of natural populations and opportunities for sustainable fishing opportunities. Productive, accessible habitat is essential for the long-term viability and productivity of steelhead populations.

Findings and Recommendations:

- **Degradation of riverine, estuarine, and nearshore habitat has resulted in the loss of an average of 83% of the potential production of the 42 steelhead populations assessed in Washington.** Improvements in habitat protection measures and restoration of degraded or inaccessible habitat are essential to assure the long-term viability of natural populations of steelhead in Washington. (Chapter 7, Finding 2)

Recommendation. Ensure that the technical expertise of WDFW is available to local planning groups and governments to assist in the identification of the habitat factors reducing the viability of steelhead populations. Provide web access to map-based information on the stream reaches of high value for protection and restoration actions. (Chapter 7, Recommendation 2)

*Recommendation***.** Enhance the ability of local planning groups to effectively pursue new funding opportunities and efficiently use existing fund sources by developing a web application that identifies a schedule of priority habitat protection areas and restoration projects. (Chapter 7, Recommendation 3)

Recommendation. Through a recently initiated project to evaluate the feasibility of developing habitat conservation plans for the Hydraulic Project Approval (HPA) program, and for WDFW owned and managed wildlife areas: a) assess the potential impacts of WDFW land management activities on steelhead; b) assess the potential impacts of HPA-permitted activities on steelhead; c) evaluate potential conservation measures to fully mitigate for adverse impacts resulting from HPA permitted activities; d) identify HPA activities that will require new research or monitoring efforts to assess impacts and potential mitigation measures; and e) develop tools and strategies to facilitate the monitoring, tracking, and adaptive management of HPA activities. (Chapter 7, Recommendation 4)

Recommendation. Develop and implement a consistent method for using remote sensing data to monitor trends in the status of habitat. Many planning forums require or would benefit from information about the status and trends of habitat across Washington State. This coarse-scale information, in various forms, is widely available through remote sensing but little effort has been given to standardizing products to meet multiple stakeholder needs simultaneously or in providing a template upon which future updates can made. (Chapter 7, Recommendation 5)

Recommendation. Develop improved tools that relate environmental factors (e.g., climate, water temperature, stream flow) and the physiological status (e.g., length, growth rate) of juvenile *O. mykiss* to the diversity, spatial structure, abundance, and productivity of steelhead populations. (Chapter 2, Recommendation 2)

- **The status of steelhead populations varies substantially across Washington.** Over 90% of the populations in the Olympic Peninsula region and over 60% in the Southwest Washington region were rated as "Healthy". However, less than 20% of the steelhead populations were rated as "Healthy" in the five remaining regions of Washington. Yet, recent data does suggest some reason for optimism. Possibly due to improved marine conditions, the average escapement for steelhead populations throughout Washington increased by 48% in the years 1999 through 2004 relative to the prior 5 years. (Chapter 7, Finding 3)

- **Population viability analysis identified thirteen populations of steelhead with the potential for substantive conservation concerns.** The population viability analysis (PVA) conducted for this paper can be used as a tool to filter data and identify populations with a potential conservation concern. However, additional information is needed to fully assess the risk of extirpation. PVA can be misleading, particularly where population structure is uncertain or, as in the case with this analysis, the potential contribution of rainbow trout to population performance was not considered. (Chapter 7, Finding 4)

Recommendation. Reassess the status of all populations in Washington on a 4 to 8 year cycle to assure that opportunities for early action are not missed. Use PVA to filter spawner abundance data and, for populations identified to have a potential conservation concern, broaden the analysis to evaluate the contribution of rainbow trout to population viability, the previous performance of the population, and factors affecting population status. (Chapter 7, Recommendation 5)

Recommendation. Annually monitor and review the status of populations at risk, identify limiting factors, and assess the effectiveness of management actions. If necessary, implement new programs to address limiting factors, and potentially initiate "rescue programs" like kelt reconditioning or hatchery supplementation to conserve natural populations until limiting factors are addressed. (Chapter 7, Recommendation 6)

- **The inability to monitor the escapement of populations introduces significant uncertainty and risk into the management of steelhead in Washington.** The status of 47% of the steelhead populations could not be rated because of the lack of a time series of escapement or other abundance data. (Chapter 7, Finding 1)

Recommendation. Prioritize monitoring, solicit funding, develop alternative estimation methods and sample designs, and enlist the assistance of other organizations to increase the percentage of populations assessed on a regular basis. (Chapter 7, Recommendation 1)

Artificial Production

Hatchery-based production is a tool that can be used to increase fishing opportunities, conserve at-risk natural populations, or facilitate research, monitoring, and evaluation. Use of the tool is not without risks. Possible impacts can include reductions in the diversity and fitness of natural populations, deleterious ecological interactions with natural populations and other species, and migration impediments resulting from the construction of hatchery facilities. An important step in the evolution of hatchery management has been the explicit definition of two genetic strategies – integrated or isolated – for the management of hatchery broodstock. Integrated programs intend that fish of natural- and hatchery-origin become fully reproductively integrated as a single population. Isolated programs (sometimes called segregated) intend for the hatchery population to represent a distinct population that is reproductively isolated from naturally spawning populations.

Findings and Recommendations:

- **The recreational fishery for hatchery-origin steelhead provides substantial fishing opportunities and economic benefits.** In the nine seasons from 1995-1996 through 2003-2004, recreational anglers harvested an average of 99,300 hatchery-origin steelhead. The estimated expenditures by recreational fishers associated with the catch of hatchery-origin steelhead were approximately $99 million dollars per year, with an economic output (includes revenues generated indirectly) of $188 million dollars per year. (Chapter 3, Finding 1)

- **Hatchery programs using Chambers Creek Winter or Skamania River Summer steelhead coupled with an isolated strategy comprise over 68% of the broodstock collection programs in western Washington.** Over 68% (28 of 41) of the steelhead broodstock collection programs in Puget Sound, the Olympic Peninsula, Southwest Washington, and the Lower Columbia regions collect broodstock of either Chambers Winter or Skamania Summer origin. Juveniles from these programs are generally released in watersheds where these stocks are not indigenous. The programs are operated with an isolated (also called segregated) reproductive strategy with the intent that little or no gene flow will occur between the natural and hatchery population. In contrast, hatchery programs in eastern Washington primarily rely on an integrated strategy with broodstock of local origin (5 of 7 or 71% of broodstock collection sites). (Chapter 3, Finding 2)

- **Naturally spawning adults originating from hatchery programs using the Chambers Creek Winter or Skamania River Summer stock have low reproductive success.** Six empirical studies in Oregon and Washington demonstrated that returning adults from these programs have low reproductive success in natural spawning areas. In these studies, highly domesticated hatchery-origin spawners have have been found to have only 7% to 37% of the success of natural-origin spawners in the same river. (Chapter 3, Finding 3)

- **Chambers Creek Winter and Skamania river Summer steelhead programs pose a high potential genetic risk.** Although each returning adult of Chambers Winter and Skamania Summer origin may on average have low reproductive success, substantial production of juveniles can still result from the spawning of a large number of hatchery-origin adults. When considered together with the previous two findings, this suggests that the Chambers Winter and Skamania Summer steelhead hatchery programs could pose a substantial risk to both the among-population diversity and the fitness of natural steelhead populations. Direct empirical evidence for loss of diversity is limited because genetic samples were generally not collected from natural populations before hatchery programs were initiated and the power of tests that can be applied is limited by the small number of loci (7) evaluated. Despite these limitations, 2 of the 7 (29%) natural populations sampled had significant introgression by Chambers Winter type fish during the time period evaluated. (Chapter 3, Finding 4)

- **Integrated programs are likely to be more effective at maintaining population fitness for rates of gene flow >2%.** Theoretical analysis calibrated with field studies indicates that integrated programs using a local source of broodstock will be more effective than isolated programs in maintaining the fitness of natural populations when the rate of gene flow from adults of hatchery-origin to the naturally-spawning population exceeds 2% per year. (Chapter 3, Finding 5)

    Recommendation. Evaluate the potential range of gene flow from returning adults to natural populations in all watersheds where Chambers Winter or Skamania Summer type steelhead are released. Where risks are inconsistent with policy objectives for the natural population, implement one or more of the following actions: 1) release steelhead juveniles from isolated programs only at locations where returning adults can be captured; 2) adjust the size of the program, release location, fishery harvest rate, or other factor to achieve an acceptable rate of gene flow; or 3) replace the isolated program with an integrated program developed from local broodstock. (Chapter 3, Recommendation 1)

> *Recommendation.* Design and initiate a program to monitor the genetic characteristics of steelhead populations. Prioritize the collection of samples from watersheds with both a hatchery program and a significant natural population to assess the potential loss of diversity associated with hatchery programs. (Chapter 3, Recommendation 2)
>
> *Recommendation.* Support and expand research to link changes in genetic markers to the abundance and productivity of the population. Current genetic monitoring typically assesses changes in the frequency of neutral alleles, or alleles that are not believed to have a functional effect on fitness. If we could identify genetic markers that were related to fitness, we could provide an improved assessment of what changes in the frequency of these markers mean to population productivity and other characteristics. (Chapter 3, Recommendation 3)
>
> *Recommendation*. Submit for publication in a peer-reviewed journal a paper describing the methods developed to compare the potential fitness loss associated with integrated and isolated artificial production programs. These methods may be of broad interest in the evaluation and management of artificial production programs. (Chapter 3, Recommendation 4)

- **Progeny from Chambers Creek Winter and Skamania River Summer adults that spawned naturally pose a potential risk of competition to the indigenous natural population.** Despite the limited reproductive success of some domesticated hatchery-origin spawners, the sheer number of hatchery-origin spawners in natural spawning areas can result in substantial numbers of juvenile progeny. Competition may occur with indigenous natural populations, but the potential magnitude of the effects is extremely difficult to quantify. (Chapter 3, Finding 6)

> *Recommendation.* Evaluate the potential effects of competition when considering the relative risks and benefits of isolated programs, particularly if conservation concerns exist. Where risks are inconsistent with policy objectives for the natural population, implement one or more of the actions described in Recommendation 3-1. (Chapter 3, Recommendation 5)

- **Integrated artificial production programs can increase the number of natural spawners and improve the productivity of the composite population, but the long-term effectiveness of these programs has not been conclusively demonstrated.** Successful implementation of an integrated program requires careful consideration of the number and characteristics of natural-origin broodstock, the incidence of hatchery-origin adults in natural spawning areas, and the juvenile release strategy (location and time of release; size and smolting status of juveniles at release). While integrated programs have proven effective in increasing the abundance and productivity of the composite population in the short-term, long-term impacts on diversity, spatial structure, and the potential loss of productivity associated with domestication have not been thoroughly evaluated. Long-term effectiveness also depends on maintenance and improvement of the productivity of natural habitat. Interactions between habitat, hatchery, and harvest are discussed further in Chapter 4. (Chapter 3, Finding 7)

> *Recommendation.* Evaluate the potential effects of integrated programs on the diversity, spatial structure, abundance, and productivity of the indigenous natural population. Carefully consider the size of the program and characteristics of the release strategy (location, time, size of fish) to assure that potential genetic and ecological risks are consistent with policy objectives. (Chapter 3, Recommendation 6)

- **Survival rates for steelhead released from Puget Sound programs are currently the lowest of any region within the state.** Survival rates for winter steelhead released from hatchery programs in Puget Sound dropped to an average of <0.4% for the 1995 through 1998 brood years. The survival rates are currently the lowest of any region within the state, including the Upper Columbia River and the Snake River, and appear to have resulted from a significant shift in the conditions encountered during early marine rearing in Puget Sound and the Georgia Basin. (Chapter 3, Finding 8)

> *Recommendation.* Develop a "population rescue" reference document that discusses the conditions under which a hatchery conservation program may be warranted and the key questions that should be addressed during the development of the program. (Chapter 3, Recommendation 7)
>
> *Recommendation.* Evaluate the fishery and economic benefits of isolated hatchery programs in Puget Sound relative to those of hatchery programs for other salmonid species and the potential benefits of conservation programs for natural steelhead populations. If necessary, adjust programs to provide enhanced economic and conservation benefits. (Chapter 3, Recommendation 8)

Management

The underlying paradigm for fisheries management is rapidly shifting from an approach that focused simply on the abundance of a single species to multi-attribute populations assessments and community ecology. In an appeal for a new era in fisheries management, Walters and Martell (2004) suggest that "the central objective of modern fisheries science should be to clearly expose trade-offs among conflicting objectives, and the central objective of fisheries management should be to develop effective ways to decide where to operate along the trade-offs, and how to operate successfully."

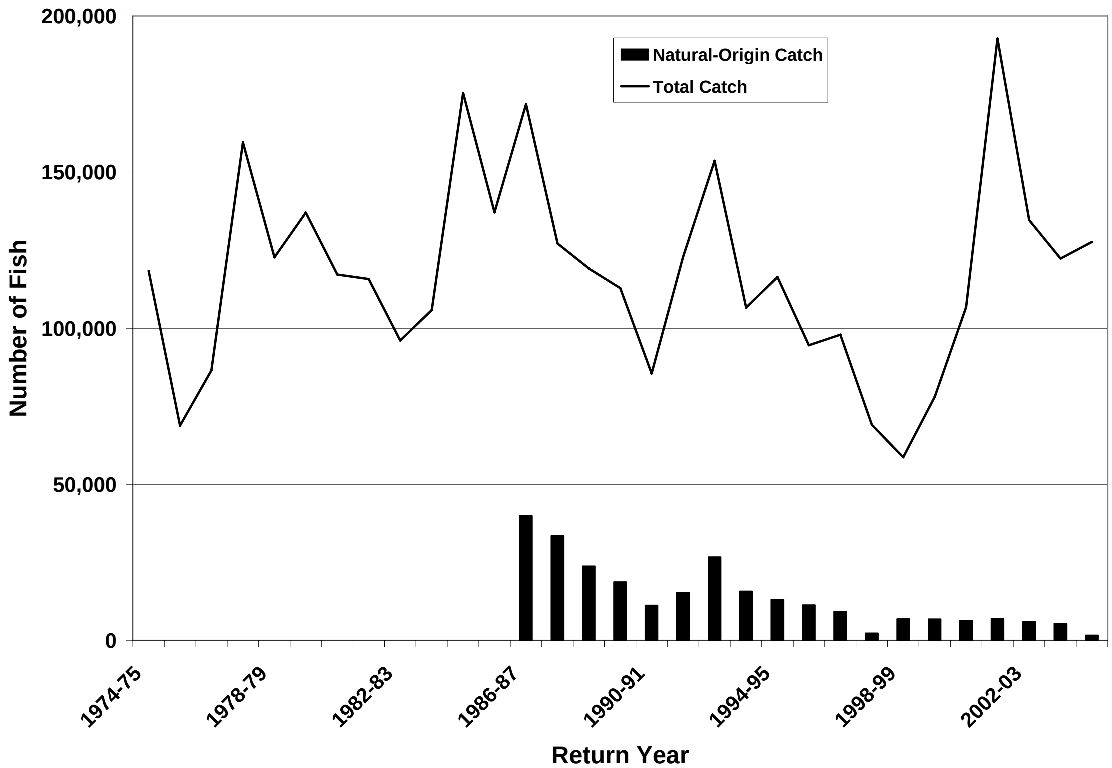
Findings and Recommendations:

- **Steelhead fisheries are an important part of the cultural heritage of Washington and provide substantial economic benefits.** Steelhead and anadromous salmonids are of nutritional, cultural, and economic importance to Native American tribes. Known for their explosive power and their preference for fast-flowing rivers, these fish have long held a special place in the lore of Northwest anglers. Recreational fishers spent an average of $105 million dollars per year fishing for steelhead during the last decade with an associated economic output of over $200 million dollars per year. (Chapter 4, Finding 1)

- **The diverse life histories of steelhead introduce management complexity.** Juvenile *O. mykiss* observed in freshwater may have originated from resident or anadromous parents, and anadromous parents may be of summer or winter return-timing. This diversity can make the collection and interpretation of juvenile genetic or abundance data difficult.

  The adult run of steelhead may be comprised of fish with multiple return-timing (summer and winter), a variable number of years of freshwater and marine residence, and adults that previously spawned. Understanding the effects of the environment and the number of spawners on the dynamics of the population requires age and run-timing specific estimates of fishing mortality and escapement. In some populations, further management complexity may be introduced by the contribution of resident *O. mykiss* to the production of steelhead. (Chapter 2, Finding 2)

- **Management of steelhead fisheries is based on a complex web of federal and state court orders, federal regulations associated with the Endangered Species Act, and state statutes.** Many steelhead fisheries in Washington are managed cooperatively with Native American tribes in a unique government-to-government relationship defined by treaties, court decisions, and legislation. The *U.S. v. Washington* and *U.S. v. Oregon* decisions determined that the Treaty Tribes and non-Indians are each entitled to a fair share of fish, defined as equal shares of harvestable salmon or steelhead. (Chapter 4, Finding 2)



- **The recreational catch of steelhead has fluctuated cyclically during the last 30 years, ranging from approximately 193,000 in the 2001-2002 season to a low of less than 59,000 in the 1998-1999 season.** Variations in the recreational catch can reflect many factors, including the abundance of steelhead, the catchability of steelhead as affected by conditions such as stream flow, and fishing regulations. Four peaks in the catch of steelhead are evident during the 30 years, separated by approximately by 7 to 9 year periods of declining catch. (Chapter 4, Finding 3)

- **The percentage of the recreational catch of steelhead originating from natural production has declined from 26% in the 1987-1988 season to approximately 1% in the 2004-2005 season.** The cautious management approach implemented by WDFW in the mid-1980s, including mark-selective fisheries, has effectively reduced the catch of natural-origin steelhead while providing opportunities to harvest steelhead of hatchery-origin. (Chapter 4, Finding 4)

- **Angler interest in catch-and-release fisheries has increased relative to 1987.** Phone surveys indicate that anglers are becoming more likely to release steelhead that can be legally retained. In the 1987 survey, anglers indicated that an average of 14%

of the steelhead landed were released; this increased to 40% in 1995 and 42% in 2003. (Chapter 4, Finding 5)

- **Achieving management goals for steelhead will be promoted by an integrated strategy for habitat protection and restoration, hatchery practices, and harvest management.** A strategy describes the general approach that will guide management actions in the pursuit of a desired future state. Strategies for habitat, harvest, and hatchery production, often referred to as the all-H sectors, have often been developed and evaluated in isolation. Misalignment of strategies can result in unexpected population and ecosystem responses and can make it difficult to achieve goals. (Chapter 4, Finding 6)

- **Management of steelhead requires evaluation of the trade-offs between conflicting objectives and an effective process for determining where to operate along these trade-offs.** Embedded in this paraphrasing of Walters and Martell (2004) are three important implications: 1) achieving all management objectives is rarely possible; 2) explicit evaluation of trade-offs promotes discussion and the development of improved strategies; 3) selection of strategies is not simply a technical analysis, but requires extensive communication and discussion with stakeholders. Trade-offs likely to be encountered in the management of steelhead include habitat quality versus spawner abundance, harvest level versus the fitness of the natural population, and population diversity versus versus harvest level. (Chapter 4, Finding 7)

> *"…the central objective of modern fisheries science should be to clearly expose trade-offs among conflicting objectives, and the central objective of fisheries management should be to develop effective ways to decide where to operate along the trade-offs, and how to operate successfully."*
>
> *Carl J. Walters & Steven J.D. Martell*
> *Fisheries Ecology and Management*

> *Recommendation.* Develop and implement improved methods and forums to inform constituents about steelhead management trade-offs, generate and discuss new strategies, and solicit review and comment on alternative strategies. In addition to the existing Fish and Wildlife Commission process and the Steelhead and Cutthroat Policy Advisory Group, these methods could include informal workshops and focus groups. (Chapter 4, Recommendation 1)

> *Recommendation*. Building on the concepts developed in this paper, develop and apply on a population specific basis analytical tools to evaluate trade-offs between competing management objectives. (Chapter 4, Recommendation 2)

> *Recommendation*. In conjunction with the fishery comanagers, continue to annually assess the predicted abundance of steelhead populations, identify

allowable fishing rates, and monitor the impacts of fisheries. (Chapter 4, Recommendation 3)

- **The complex reproductive and ecological interactions between anadromous and resident forms of O. mykiss may necessitate a holistic assessment of management actions.** Initial research suggests that extensive reproductive and ecological interactions can exist between resident and anadromous *O. mykiss* in some watersheds. These interactions can include breeding between resident and anadromous forms and the production of anadromous progeny from one or more resident parents. Where substantial interactions occur, predicting or understanding the response of the population to management actions will require a holistic assessment of resident and anadromous *O. mykiss*. (Chapter 2, Finding 3)

  Recommendation. Build on studies in the Cedar River, Yakima River, and other locations to develop a better understanding of the relationship of resident and anadromous *O. mykiss*. From these studies, develop improved tools to assess the potential effects of management actions and enhanced management strategies that effectively address resident and anadromous life history forms. (Chapter 2, Recommendation 3)

Additional Challenges and Opportunities

During the development of this report, we identified new genetic and geographic information system analyses that would substantially enhance the management of steelhead.

Findings and Recommendations:

- **The population structure of steelhead in the Puget Sound, Olympic Peninsula, and Southwest Washington regions is uncertain.** Inadequate genetic samples are currently available and new tools developed and applied by technical recovery teams have not been systematically applied in these regions. (Chapter 5, Finding 2)

  Recommendation. Evaluate the population structure of steelhead in the Puget Sound, Olympic Peninsula, and Southwest Washington regions. Evaluate assumptions of the 1992 comanager analysis and, building on the tools developed by the Puget Sound, Willamette/Lower Columbia, and Interior Columbia technical recovery teams, define and implement a consistent procedure for evaluating population structure. (Chapter 5, Recommendation 2)

- **Steelhead life history diversity creates significant challenges for adequate sampling and accurate genetic analysis.** Genetic analysis is potentially a powerful tool for identifying population and metapopulation structure. However, genetic analyses of previous samples from juveniles of potentially mixed life history types were often inconclusive. Newer genetic markers, such as single nucleotide polymorphisms (SNPs) and microsatellites, may enhance the power of genetic analyses, but the development and implementation of improved sampling protocols will be required. (Chapter 5, Finding 3)

  Recommendation. Focus future collection of genetic samples in areas with significant uncertainty in population structure. Collect genetic samples for microsatellite or SNP analysis with methods that assure run timing and life history type are known. Conduct analyses using high-resolution DNA markers appropriate to research objectives. (Chapter 5, Recommendation 3)

- **A geographic information system (GIS) provides a powerful, cost-effective tool to analyze and present spatial data.** Mapping the characteristics of habitat and distribution of redds now and in the future will be invaluable as we begin to assess the effectiveness of improved management strategies and recovery actions. (Chapter 6, Finding 3)

Recommendation. Enhance GIS capabilities by creating spatial data layers that identify barriers to fish passage, by incorporating additional variables into the model developed in this paper for predicting fish distribution, and by annually mapping the distribution of redds. (Chapter 6, Recommendation 3)